Revealing the meaning of the asymptotic matching across the resistive resonant layer in MHD

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In the high temperature plasma of tokamaks, the macroscopic magnetic perturbations preserve poloidal and toroidal magnetic fluxes, both of which are frozen into the plasma. Only at the plasma edge (or plasma-vacuum interface) and at the resonant surfaces the highly localized currents are excited, which cause local violation of the flux frozenness into the plasma. At the resonant surface the resistive diffusion leads to formation of magnetic islands.

In this presentation we consider the situation, which is marginally unstable to the resistive MHD modes. In the absence of pressure gradient, it is well described by the asymptotic Delta-prime theory of the tearing modes. In this case 2 MHD solutions outside the resistive layer behave like $u_1(x) = x$ and $u_0(x) = 1 + au_1 \ln|x| + bx$, where x is the distance from the resonant surface. The coefficients in front of them are determined by the left and right boundary matching conditions.

The matching technique uses only this so-called "ideal" solutions to judge about resistive instabilities. In particular, the most essential information about the threshold is determined by condition that u_0, u_1 match each other from both sides at $x \to 0$.

In the presence of p' the behavior is different: $u_0 \to |x|^{-\nu}$, $u_1 \to x|x|^{\nu}$, and $u_1/u_x \to x|x|^{2\nu}$ with ν proportional to p' and inverse proportional to local shear s. The question is what would be the meaning of matching both solutions when, e.g., $\nu > 1$. In this case, the disconnection in the small solutions does not even perturb the value of the second derivative in the total solution, so even the current density remains unperturbed.

This question has a practical importance, e.g., for spherical tokamaks where the low shear in the core corresponds to the discharges with the highest achievable beta. When the high-β plasma approaches the ideal stability limit, it should face first the resistive stability limit. But in this case the ν exponent can exceed 1, and it is necessary to understand what would be meaning, if any, of the matching technique.